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METHOD AND APPARATUS FOR IMPROVING PERFORMANCE OF A SPLITTERLESS ASYMMETRIC DIGITAL SUBSCRIBER LINE (ADSL)

INVENTORS:

FIELD OF THE INVENTION

The present invention relates generally to voice and data communications over digital subscriber lines and, more particularly, to a method and apparatus for improving the performance of a splitterless Asymmetric Digital Subscriber Line (ADSL).

BACKGROUND OF THE INVENTION

While telephone lines are useful for data communications using modems, the data rates than can be achieved over ordinary telephone lines are rather limited. Attempts have been made to re-engineer existing telephone lines for digital data communications. These include Integrated Services Digital Network (ISDN) and, more recently, Digital Subscriber Lines (DSLs). Since most computer users tend to receive more data than they send, Asymmetric Digital Subscriber Lines (ADSLs) having different bandwidths for reception and transmission have been favored over regular DSLs.

In order to maximize the utility of the existing copper cable plant, ADSL has been implemented to allow an ordinary POTS ("plain old telephone service") communication channel to coexist with the ADSL data communication capacity. However, originally, ADSL required a POTS splitter to be installed at the point where the ADSL enters a business or residence. The POTS splitter separated the POTS communication channel from the ADSL data communication channel allowing ordinary telephone instruments to receive/transmit over the POTS communication channel without the need for any sort of adapters.

Unfortunately, a certain amount of specialized knowledge is required in order to properly install the POTS splitter. Thus, a version of ADSL known as splitterless ADSL or G.Lite was developed. Splitterless ADSL avoids the need for a POTS splitter at the customer premises. However, since there is no splitter to separate the ADSL data from the POTS voice signals, the ADSL data is present at telephone jacks throughout the subscriber's home or business. This ADSL data may become corrupted if incompatible telephone instruments are plugged into the telephone jacks.

The G.Lite variant of ADSL has also been referred to as universal ADSL, by the Universal ADSL Work Group (UAWG). One of the goals of UAWG is to develop an ADSL technology that allows simple modem installation by the end user. This refers to G.Lite's promise to allow telephone companies to provision ADSL and allow customers to set up G.Lite DSL connections on their own - without the delay and expense of a telephone company service call.

The standard for G.Lite arises from a series of technical requirements which were approved at the October, 1998, meeting of the ITU (International Telecommunications Union – a group headquartered in Geneva, Switzerland). The ITU's Study Group 15 Q4 called the technology G.Lite. The ANSI (American National Standards Institute) T1/E1.4 committee and the ADSL Forum (an industry group) call it splitterless ADSL or Lite ADSL.

The original installation concept in ADSL required a centralized POTS splitter to be installed on the telephone line usually at the NID (network interface device). The purpose of this POTS splitter is to split the frequency range into two isolated bands - a telephone (POTS) band and an ADSL band.

The implications of the above installation concept are that installation of the POTS splitter is non-trivial and that there is a need to install new wiring from the NID to the ADSL modem. As a result, installation of ADSL will not be readily installed by end users. It will require, in most cases, the assistance of the telephone company.

The G.Lite modem uses the existing home wiring (used today for POTS), so the installation becomes simple. ADSL Lite and POTS operate together on the same internal home wiring system, allowing the customer to plug both a telephone and a modem into a standard wall telephone outlet.

When a phone goes off-hook, noise is generated from the phone in the same frequency range as the ADSL signal (because of non-linear effects). Furthermore, the impedance of an off-hook phone may be so low that it essentially shunts the strength of the ADSL signal. The increase of noise and decrease of signal will

usually cause errors in the ADSL signal, which will requirc a re-start process in order to re-sync. The opposite can happen as well. The ADSL signal can sometimes be heard as an annoying sound in the telephone.

A small lowpass filter (micro-filter) may be installed in series with the telephone apparatus to filter out the interference between the data signals and the voice signals. The micro-filter behaves as a distributed POTS splitter, i.e., instead of installing a splitter at the NID, as in G.Lite modems, the customer may instead install a micro-filter on the most problematic phones, or even on all phones.

When the micro-filter (low-pass filter) is installed between the wall jack and the telephone, it isolates the phone from the modem. The phone will not influence the modem and the ADSL transmit signals will be filtered out before entering the phone.

In order to cope with the disruptive interference of phones on the ADSL signal and the annoying interference of ADSL signals into a telephone when a micro-filter is not used, the modem must retrain when one of the phones goes off-hook. This fast retrain takes about one or two seconds and allows the modem to adapt itself to the new condition.

During the fast retrain, the service stops and is reestablished afterwards. This interruption is undesirable and is considered to be one of the main disadvantages of ADSL Lite. Putting the phone back on-hook requires another fast retrain routine since the off-hook settings of the modem are not optimal for the on-hook case.

G.Lite modem installation involves the use of at least one micro-filter in the majority of homes. Micro-filtering may be required in order to make G.Lite work at fast bit rates or in some cases to allow it to work at all.

A significant percentage of corded phones require a micro-filter in order to meet minimum standards for audible interference in the off-hook condition. However, some cordless phones do not require a micro-filter and behave as if a micro-filter is already installed inside. In both cases (phones with micro-filters and cordless phones), fast retrain is not a necessity when phones go off-hook or return to on-hook.

However, many telephones do require a modem to retrain when the telephones transition between on-hook and off-hook states. Thus, a technique is needed to distinguish efficiently between situations where retraining is needed and where it is not.

SUMMARY OF THE INVENTION

The present invention provides a method and apparatus for improving the performance of splitterless ADSL systems. While ideally users would install lowpass filters on all telephones when using splitterless ADSL, it can be expected that users will neglect to do so in some cases. Some telephones, when switching between on-hook and off-hook states, will cause interference with ADSL data, while others will not. The present invention provides a uniform technique for adapting an

ADSL system to any of these situations. The invention provides a graduated approach to handling anomalies that may be caused by incompatible telephone equipment.

One embodiment of the invention attempts to correct anomalous situations without having to interrupt the data communication. If more information is needed, a very brief channel echo measurement is conducted. Only if the problem cannot be resolved at this point is retraining of the modem performed. This approach greatly minimizes interruption of data communication and reduction of bandwidth.

Another embodiment of the invention reduces the transmitted signal level to its lowest practical value to minimize interference with telephone equipment. Multiple levels of signal reduction are available, and user input may be obtained to optimize the transmit signal level.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram illustrating an embodiment of the present invention with off-hook detection occurring at the ADSL Transceiver Unit-CO side (ATUC).

FIG. 2 is a block diagram illustrating an embodiment of the invention with off-hook detection occurring at the ADSL Transceiver Unit-Remote side (ATUR).

FIGS. 3A and 3B are a flow diagram illustrating a process for controlling retraining or adaptive attenuation according to one embodiment of the invention.

FIGS. 4A and 4B are a flow diagram illustrating a process for determining if retraining is needed and, if necessary, performing retraining according to one embodiment of the invention.

FIG. 5 is a flow diagram illustrating a process for determining if retraining is needed and, if necessary, performing retraining according to one embodiment of the invention.

FIG. 6 is a flow diagram illustrating a process for adaptive attenuation according to one embodiment of the invention.

FIG. 7 is a flow diagram illustrating a process for adaptive attenuation according to one embodiment of the invention.

FIG. 8 is a flow diagram illustrating a process for user-selected adaptive attenuation according to one embodiment of the invention.

FIG. 9 is a flow diagram illustrating a process for detecting the state of a telephone hookswitch according to one embodiment of the invention.

DETAILED DESCRIPTION OF THE INVENTION

The present invention is directed to a method and apparatus for improving the performance of a splitterless ADSL system. The invention provides benefits for both improved data communications and improved voice communications. The procedure for managing decisions to retrain the ADSL modems reduces the amount of time the ADSL is unavailable for data communications. According to the present invention, an adaptive attenuation technique reduces the likelihood that transmitted ADSL data will interfere with telephone conversations conducted over the POTS feature of the ADSL.

FIG. 1 is a block diagram illustrating an embodiment of the present invention with off-hook detection occurring at the ADSL Transceiver Unit-CO side (ATUC). Customer premises equipment (CPE) 101 is coupled to central office (CO) 102 via digital subscriber line (DSL) 103. CPE 101 includes highpass filter 104, lowpass filters 105 and 106, ADSL modem 107, computer 108, and telephone instruments 109 and 110. Computer 108 is coupled to ADSL modem 107, which is coupled to highpass filter 104, which is coupled to DSL 103. Telephone instrument 109 is coupled to lowpass filter 105, which is coupled to DSL 103. Telephone instrument 110 is coupled to lowpass filter 106, which is coupled to DSL 103.

CO 102 includes off-hook detector 117, POTS ("plain old telephone service") splitter 111, ADSL modem 112, data switch 113, voice switch 114, data network 115, and voice network 116. DSL 103 is coupled to off-hook detector 117, which is coupled to POTS splitter 111. Off-hook

detector 117 also provides an output to ADSL modem 112. POTS splitter 111 is coupled to voice switch 114 and to ADSL modem 112. ADSL modem 112 is coupled to data switch 113. Voice switch 114 is coupled to voice network 116. Data switch 113 is coupled to data network 115.

Off-hook detector 117 monitors the electrical characteristics of DSL 103 to determine the status of the hookswitches of telephone instruments 109 and 110. Off-hook detector 117 can detect if either or both of telephone instruments 109 and 110 go to an off-hook state. For example, off-hook detector 117 can monitor the voltage across DSL 103 or the current through DSL 103 to determine the status of the hookswitches. Since closure of a hookswitch causes considerable current to flow through the subscriber loop, current through DSL 103 can be readily detected. For example, a low-value resistor may be placed in series with DSL 103 and the voltage across the resistor measured to determine current flow. Alternatively, current flow may be detected using other devices, such as optocouplers or mechanical sensors. Since subscriber loops typically have a high source impedance, substantial voltage drops tend to occur as current through the loop increases. For this reason, current flow can be detected by simply measuring the voltage across DSL 103 without the need to insert additional components in the current path.

Since this embodiment involves detection of an off-hook condition using an off-hook detector at CO 102, procedures for accommodating the off-hook condition are initiated at CO 102. If off-hook detector 117 detects a change of hookswitch status, it passes a signal to ADSL modem 112. ADSL modem 112 initiates testing to determine if a modem retraining routine is indicated. If so, it communicates this information to ADSL modem 107 at CPE 101 via DSL 103. ADSL modem 112

and ADSL modem 107 then determine and implement any required retraining routine and reestablish an efficient communications link.

FIG. 2 is a block diagram illustrating an embodiment of the invention with off-hook detection occurring at the ADSL Transceiver Unit-Remote side (ATUR). CO 204 includes POTS splitter 111, ADSL modem 112, data switch 113, voice switch 114, data network 115, and voice network 116. DSL 205 is coupled to POTS splitter 111. POTS splitter 111 is coupled to ADSL modem 112 and voice switch 114. ADSL modem 112 is coupled to data switch 113. Data switch 113 is coupled to data network 115. Voice switch 114 is coupled to voice network 116.

At the customer premises side, computer 108 is coupled to ADSL interface 201. ADSL interface 201 includes ADSL modem 202 and off-hook detector 203. ADSL modem 202 is coupled to off-hook detector 203. ADSL modem 202 and off-hook detector 203 are coupled to DSL 205. Telephone instrument 109 is coupled to lowpass filter 105, which is coupled to DSL 205. Telephone instrument 110 is coupled to lowpass filter 106, which is coupled to DSL 205.

Off-hook detector 203 is coupled to DSL 205 and is configured to detect the status of any hookswitch associated with any telephone instrument on DSL 205, for example telephone instruments 109 and 110. Off-hook detector 203 may be configured in any manner that allows it to detect the electrical characteristics of DSL 205. As an alternative, off-hook detector 203 may be interposed between ADSL modem 202 and DSL 205.

Since off-hook detector 203 is associated with ADSL modem 202 of the CPE, requests for corrective action arising from the sensing of hookswitch events will be initiated by ADSL modem 202 of the CPE. If appropriate, ADSL modem 202 transmits a request via DSL 205 to ADSL modem 112 to arrange whatever action may be indicated, for example, performing an echo channel measurement or initiating a request for retraining.

FIGS. 3A and 3B are a flow diagram illustrating a process for controlling retraining or adaptive attenuation according to one embodiment of the invention. The process begins at step 301. In step 303, a decision is made as to whether or not the hookswitch status has changed. This information may be provided by off-hook detector 117 or off-hook detector 203, depending on the particular configuration being used. If there has been no change in the hookswitch status, the process remains at step 303. If, however, a change of hookswitch status has been observed, the process continues to step 304. In step 304, a decision is made as to whether or not a retraining routine is needed. If so, retraining is performed in step 305. Retraining resets the modem parameters to conform to the actual conditions of the DSL. If retraining is not needed or after retraining has been completed, the process continues to step 306.

In step 306, a decision is made as to whether or not power adjustment is needed. If the power level at which data communications signals are being transmitted is too high, it is more likely to interfere with any telephone apparatus that is also coupled to the DSL. If the power level is too low, it is more likely to cause errors in the data communications. Thus, if an adjustment of the power level is needed, the power level is adjusted in step 307. If no adjustment of power level is needed or after

a power adjustment is completed, the process continues to step 309 via reference 308. In step 309, a decision is made as to whether or not a different profile is appropriate. The profile specifies parameters used by the modem to adapt to the conditions of the DSL. One example of a situation in which a different profile might be appropriate is when voice communications traffic is present on a DSL. The presence of the voice communications traffic may reduce the signal-to-noise ratio for the data communications through the ADSL modem. Thus, it would be appropriate to select a profile more appropriate to the degraded signal-to-noise conditions.

If a different profile is appropriate, an appropriate profile is selected in step 310. If there is no need to change profiles or the selection of an appropriate profile has been completed, the process returns to step 303 via reference 302.

FIGS. 4A and 4B are a flow diagram illustrating a process for determining if retraining is needed and, if necessary, performing retraining according to one embodiment of the invention. The process begins in step 401. In step 403, a decision is made as to whether or not the hookswitch status of any telephone instrument on the DSL has changed. If not, the process remains at step 403. If, however, a change in the hookswitch status has been detected, for example by off-hook detector 117 or off-hook detector 203, the process continues to step 404. At step 404, a decision is made as to whether or not the channel transfer function has changed. The transfer function characterizes how the channel will respond to signals applied to it. If the channel transfer function has changed, the process continues to step 413 via reference 405. In step 413, modem retraining is performed to adapt the modems to the new transfer function. After the retraining, the process returns to step 403 via

reference 402. If, in step 404, the transfer function is determined not to have changed, the process continues to step 406.

In step 406, the ATUR schedules echo channel estimation with the ATUC. In step 407, the ATUC acknowledges echo channel estimation scheduling with the ATUR. In step 408, according to the agreed schedule, the ATUC stops transmitting data. In step 409, the ATUR performs an echo channel estimation procedure by transmitting a known signal and monitoring the DSL to see how it responds to the known signal. From step 409, the process continues in step 411 via reference 410. In step 411, the ATUC and ATUR resume normal communications. In step 412, a decision is made as to whether or not the results of the echo channel estimation procedure indicate a need for retraining. If not, the process returns to step 403 via reference 402. If so, retraining is performed in step 413, and the process returns to step 403 via reference 402.

FIG. 5 is a flow diagram illustrating a process for determining if retraining is needed and, if necessary, performing retraining according to one embodiment of the invention. The process begins in step 501. In step 502, line quality information, such as the state of the off-hook detector, the channel transfer function, the echo measurement, the error rate, the noise margin, and the change in noise margin, are obtained. This information may be obtained from a variety of sources, for example, from hardware apparatus, such as an off-hook detector, or from software records of events such as transmission errors. In step 503, a decision is made, based on this information, whether or not

retraining is indicated. If not, the process returns to step 502. If so, retraining is performed in step 504. From step 504, the process returns to step 502.

FIG. 6 is a flow diagram illustrating a process for adaptive attenuation according to one embodiment of the invention. The process begins in step 601. In step 602, a measurement is made of the signal loss associated with the subscriber loop. Alternatively, this information may be derived from parameters stored during the original modem training routine or the most recent retraining routine.

In step 603, an amount of signal level reduction is calculated based on the loss measurement obtained in step 602, the present signal level being transmitted, and the known minimum signal level requirements. The signal level reduction is calculated to ensure that an adequate signal level reaches the ADSL modem at the opposite end of the DSL with a reasonable safety margin, but that the signal level is near the minimum acceptable signal level. By minimizing the signal level, interference from telephone instruments that results in distortion of the ADSL modem signals is avoided.

FIG. 7 is a flow diagram illustrating a process for adaptive attenuation according to one embodiment of the invention. The process begins in step 701. In step 702, a decision is made as to whether or not a telephone instrument is off-hook, based on its hookswitch status, for example, as detected by an off-hook detector. If not, the process remains at step 702. If a telephone instrument is determined to be off-hook, the process reduces the signal level in step 703. In step 704, a decision is made as to whether or not the telephone instrument is still off-hook. If so, the process remains at

step 704. If not, the process continues at step 705, where the signal level is increased. From step 705, the process returns to step 702.

FIG. 8 is a flow diagram illustrating a process for user-selected adaptive attenuation according to one embodiment of the invention. The process begins in step 801. In step 802, multiple signal level settings are determined. For example, one setting might be the lowest possible signal level setting given the loss of the DSL and the minimum required signal level for reliable reception. Other settings might be incrementally higher signal levels.

In step 803, a user selection is obtained from among the multiple signal level settings. The user might choose the lowest signal level setting to minimize interference with telephone instruments or a somewhat higher level setting to reduce the likelihood of errors resulting from an insufficient signal-to-noise ratio. In step 804, a signal level is set according to the selection obtained from the user in step 803. In step 805, the process ends.

FIG. 9 is a flow diagram illustrating a process for detecting the state of a telephone hookswitch according to one embodiment of the invention. The process begins in step 901. In step 902, detection routines are periodically activated. These routines attempt to detect changes in ADSL modem operation, such as increased error rates and retries. In step 903, a decision is made as to whether or not there has been a change in the ADSL modem performance. If not, the process returns to step 902. If changes of sufficient magnitude that are sufficiently correlated with one another are detected, the determination is made that there has been a substantial change in ADSL modem

performance. In the event of a change in ADSL modem performance, the process continues at step 904. At step 904, the change in ADSL modem performance is treated as an indication of a change in the hookswitch status of telephone instruments coupled to the DSL. This process is useful when an off-hook detector is not provided, but may also be used in conjunction with an off-hook detector.

CLAIMS

The claimed invention is as follows:

1. A method for improving performance of a digital subscriber line comprising:

determining a status of a telephone hookswitch;

determining whether retraining is indicated; and

determining whether power level adjustment is indicated.

2. The method of claim 1 further comprising:

initiating a retraining routine; and

adjusting a power level.

3. The method of claim 2 wherein said step of determining whether said retraining is indicated occurs in response to said step of determining said status of said telephone hookswitch.

4. The method of claim 3 wherein said step of determining said status of said telephone hookswitch further comprises determining whether said status of said telephone hookswitch has changed.

5. The method of claim 3 further comprising the steps of:

determining whether a different modem configuration profile is appropriate; and

selecting said different modem configuration profile.

6. A method for determining whether modem retraining is indicated comprising:

determining a status of a telephone hookswitch; and

performing an echo channel measurement procedure.

7. The method of claim 6 further comprising:

determining a channel transfer function.

8. The method of claim 7 wherein said step of determining said status of said telephone hookswitch further comprises:

determining whether said status of said telephone hookswitch has changed, and

wherein said step of determining said channel transfer function further comprises:

determining whether said channel transfer function has changed.

9. The method of claim 6 wherein said step of performing said echo channel measurement procedure further comprises:

scheduling a time frame for performing said echo channel measurement procedure;

acknowledging said step of scheduling;

discontinuing transmission of data by a first modem; and

initiating transmission of an echo testing signal by a second modem; and

performing a measurement of said echo testing signal.

10. The method of claim 9 further comprising:

determining whether said measurement of said echo testing signal indicates a need for retraining.

11. The method of claim 9 further comprising:

said first modem and said second modem resuming normal communication after said step of performing measurement of said echo testing signal.

12. A method for determining whether retraining is indicated comprising:

obtaining line quality information comprising a hookswitch status, a channel transfer function, and an echo measurement; and

determining whether said line quality information indicates retraining is needed.

13. The method of claim 12 wherein said step of obtaining line quality information further comprises obtaining an error rate, a noise margin, and a change in noise margin.

14. A method for reducing distortion on a digital subscriber line comprising:

performing a channel loss measurement on said digital subscriber line;

determining a minimum required signal level; and

adjusting a signal level on said digital subscriber line to remain above said minimum required signal level.

15. The method of claim 14 wherein said step of adjusting said signal level occurs in response to a telephone hookswitch changing from being in an on-hook state to being in an off-hook state.

16. The method of claim 14 wherein said step of adjusting said signal level occurs according to a user selection from among multiple signal level settings.

17. A method for estimating telephone hookswitch status comprising:

periodically initiating detection routines;

determining whether a change in modem performance has occurred; and

characterizing said change in modem performance as an indication of change in said telephone hookswitch status.

ABSTRACT OF THE DISCLOSURE

The present invention provides a method and apparatus for improving the performance of splitterless ADSL systems. The present invention provides a uniform technique for adapting an ADSL system to any of these situations. The invention provides a graduated approach to handling anomalies that may be caused by incompatible telephone equipment. One embodiment of the invention attempts to correct anomalous situations without having to interrupt the data communication. If more information is needed, a very brief channel echo measurement is conducted. Only if the problem cannot be resolved at this point is retraining of the modem performed. This approach greatly minimizes interruption of data communication and reduction of bandwidth. Another embodiment of the invention reduces the transmitted signal level to its lowest practical value to minimize interference with telephone equipment. Multiple levels of signal reduction are available, and user input may be obtained to optimize the transmit signal level.